# Flight Testing Accelerometers

Written By

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While computer-based design has been beneficial to aircraft design, findings from actual flight test results continue to be critical in validating those computations. This has translated into a demand for more accurate accelerometers in rigorous flight test installations.

The highly competitive aircraft market requires manufacturers to explore new designs that are operationally more cost effective, as in those that use composites to trim weight, while pushing the performance envelope. This means that aerospace engineers must be attuned to new materials and structural innovations, as well as familiar with their performance limitations. All of this must be accomplished without compromising safety margins.

PCB Piezotronics, Inc. (PCB) has introduced Series 3741F, which is a new line of MEMS-based, variable capacitance, DC response accelerometers that demonstrate the attributes needed for flight test applications. The company offers several full-scale ranges from ±2g to ±200g. Featuring high sensitivities of 1,350 mV/g to 13.5 mV/g respectively, the Series 3741F differential output accelerometer is designed to make precise measurements in harsh environments and provides accurate readings while being subjected to severe vibrations over a wide temperature range.

Flight testing encompasses a number of different installations, each with its own unique requirements for the test accelerometer. Accelerometers are used to measure rigid body motion during flight load cycling. Flutter testing is conducted by mounting accelerometers on wing tips. Accelerometers are also mounted to landing gear to measure shimmy during takeoff and landing.

For all applications, the accelerometer must provide accurate low frequency measurements while rejecting high frequency noise from ancillary vibration sources. Some installations require the accelerometer to be exposed to water spray, mud splash, particle impingement icing, and temperature extremes. In such severe applications, an alternative titanium housing, hermetically sealed series 3711F is available.

The sensing element of the 3741F features a proof-mass and attachment system that are bulk micro machined from the same single-crystal silicon wafer. The movement of the proof-mass is directly affected by acceleration applied in the axis of sensitivity. The sensing element is connected as a bridge element in the circuit, with differential output voltage. Electrical characteristics of one portion of the bridge increase in value, while the other decreases when exposed to acceleration. This approach minimizes common mode noise errors and improves non-linearity.


A proof-mass is laminated between two wafers using a glass bond. This structure provides a hermetic enclosure for the proof-mass in a dry inert gas environment, providing mechanical isolation and protection. The sensing element itself is kept small through the use of cutting edge processes such as deep reactive ion etching. Modifying the stiffness of the proof-mass suspension system attains a selection of full-scale ranges between ±2g and ±200g. A high natural frequency is accomplished through the combination of a lightweight proof-mass and suspension stiffness.

Ruggedness is enhanced through the use of mechanical stops on the two outer wafers to restrict the travel of the proof-mass. Gas damping mitigates high frequency vibration inputs and allows the sensor to measure lower vibration levels. This damping mitigates the accelerometer output from saturation which can occur if the sensor is excited by random vibration. The advantage of gas over liquid damping is that gas is minimally affected by temperature changes.

Series 3741F contains conditioning circuitry that provides a high-sensitivity output. The differential signal from the sensor element is amplified and balanced using an electrically programmable, integrated circuit (IC) . This IC also provides compensation of zero bias and sensitivity errors over temperature using a continuous correction engine.

Power to the accelerometer is in the form of a simple DC voltage from +5 to +32 VDC with less than 5 mA current draw. This voltage can be derived from laboratory power supplies or other portable power sources. Initially, the power is passed through a voltage regulator which ensures clean power to the microelectronics. The benefit to flight testing is that the accelerometer may be connected directly to the aircraft DC power without the use of a separate signal conditioner, saving cost and weight.

The differential output from the new accelerometer allows the positive output signal to increase with acceleration while the negative line proportionally decreases. The output lines have a common mode voltage of 1.65 VDC above circuit ground. The result is a minimum accelerometer threshold resolution of 0.1 milli-g's rms for the ±2g rated device over a bandwidth of 0 to 250Hz. The threshold scales proportionally to 6 milli-g for the ±200g, and a bandwidth up to 1,500 Hz.

Upon completion of the accelerometer assembly, an automated calibration step is conducted at discrete temperatures over a specified temperature range. This can span -54 to +121 degree Celsius. The IC features an on-chip temperature sensor for accurate thermal corrections. The electronics also feature low pass anti-alias noise filtering and reverse polarity protection. Output impedance is <120 ohms maximum and the accelerometer output stage is capable of driving lines in the hundreds of feet along the aircraft wings or tail, back inside the fuselage to the flight data acquisition system.

Series 3741F is packaged in a hard anodized aluminum housing with two through holes for secure screw mounting. Two screws and washers are provided for both metric and SAE mounting. The axis of sensitivity is perpendicular to the mounting plane. The marking on the accelerometer cover faces the direction of positive going output. The low profile package is suitable for mounting in tight spaces or three accelerometers can be attached to a mounting block for a three axis arrangement. An optional triaxial mounting block or an alternate, the Series 3713F triaxial single ended output accelerometer, are also available from PCB.

Series 3741F is supplied with a 10 ft, four conductor integral cable that features a braided shield. This cable is supple enough to be routed around tight corners and the shield floats on the transducer end so that a single point connection can be made at the data acquisition end to avoid current loops and improve EMI protection. The cable is strain relieved at the sensor from the housing in order to minimize the possibility of fatigue failures that could be experienced in the hundreds of hours of flight testing.

PCB Series 3741F MEMS based DC response accelerometers, with their small size and ruggedness, offer multiple advantages in flight testing. The accelerometers are designed with the necessary durability to withstand the many flight test cycles required of an accelerometer, including exposure to mechanical and thermal extremes over long durations. Their self-regulating aircraft power supply, amplified output, and low noise makes them well suited for flight test.

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